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Optical & Environmental Performance of Durable Silver Mirror Coatings Fabricated at LLNL

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Optical & Environmental Performance of Durable Silver Mirror Coatings fabricated at LLNL

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Abstract: A Family of Durable Silver Mirror Designs has been fabricated at LLNL. We report here on the optical and environmental performance of the basic design, which can be cleaned with standard glass cleaner and cloth after months of exposure to outside atmosphere.

Introduction

The vacuum processes group at LLNL has been coating various size (8"-26" diameter) customer supplied substrates with durable silver coatings for the last 5 years. While the initial goal of the group was to develop a durable silver design for flash lamp reflectors used in the National Ignition Facility at Lawrence Livermore National Laboratory, latest efforts have been focused on terrestrial and space based mirrors. We have developed a family of coating designs that vary only in the wavelengths they reflect and the amount of layers used. The simplest design (4-Layers) is that used on amplifier reflectors of the National Ignition Facility at LLNL. The most sophisticated design developed to date is the design for NASA (35+ Layers) that requires high reflection down to 200nm in the ultra-violet. The most popular design (17 Layers) is that used for terrestrial astronomy, (300nm to 2.5u). One mirror design is used for the telecommunications wavelengths (1500-1600nm) and has a reflection better than 99.5%. All mirror designs mentioned show extraordinary mechanical and chemical durability over other standard aluminum and silver based mirror coatings. The basic design is shown below.[1]

Substrate M_2 M_1 M_2 M_3 $(LH)^6$ L AIR
M_1 = Silver M_2 = NiCrNx M_3 = SiNx L= SiO2 H= Ta_2O_5

Figure #1 below shows the reflection of the coating designs mentioned above.

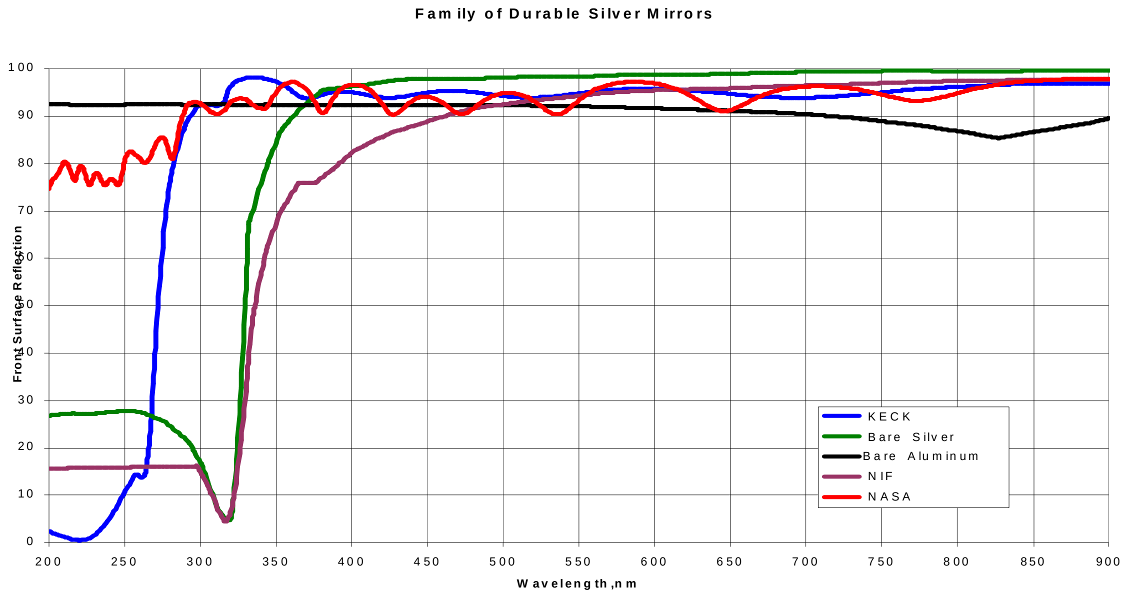

Fig.1: Family of durable silver coatings- vs - bare Al & Ag

Environmental Durability:

The coatings pass the Salt-Fog test even after scratching through the coating with a diamond scribe. They also pass a 50-eraser rub, accelerated humidity testing, 1 hour in boiling water, and a hydrogen sulfide test. The coatings can be cleaned with a standard glass cleaner and cloth when cleaning is required.

The advanced durability of these films is contributed to the following by the authors:

- Nickel-chrome (80/20 wt.%) when sputtered in Nitrogen containing environment deposits on the substrate and silver layer as an admixture of nickel and chrome nitride. Nickel does not easily bond with nitrogen, but chromium does. We found that this add-mixture of nickel-chrome nitride has about 1-2% less absorption across all wavelengths than a similar layer of nichrome metal. The nickel-chrome nitride, add-mixes with the silver metal and ties up the electrons in the silver matrix. This helps in alleviating further deterioration of the silver layer sandwiched between Nichrome-Nitride. The film also is a passivation layer for the silver layer, and helps control adhesion to the substrate and overcoat layers.

- A layer of either SiNx or AlNx must follow the NiCrNx/Ag/NiCrNx tri-layer. This prevents oxidation of the tri-layer when exposed to an oxidizing plasma or atmosphere, and also contributes to the mechanical durability of the finished dielectric enhancement stack. These two materials are the only two nitrides that are transparent in the wavelengths of interest.

- The overcoat materials (oxides or nitrides) used to enhance the reflection of the tri-layer must be amorphous. This prevents any grain – boundary migration of contaminates through grain boundaries.

Long Term Exposure Test

A long- term exposure test was started on November 11th 2004. Three 2”x 2” glass samples coated with the basic durable silver design where placed on a tray and exposed to outside Livermore air. The samples are exposed 24 hours a day to rain, sun etc. Once a month the parts are scanned by reflection on a Cary-5 spectrophotometer using the absolute reflection attachment. One of the samples is then cleaned with a standard glass cleaner a cloth and rescanned. The plan is to scan this part before and after cleaning each month for one year. The other two samples will be scanned but not cleaned until 6 months has elapsed, in which the second sample is cleaned and scanned, while the last part will be cleaned after one year. This may show if the deterioration, if any, is cumulative. We would like to stress the importance of the cleaning method used on these coatings as compared to other enhanced aluminum or silver coatings.

The coatings should be cleaned using a standard glass cleaner such as Windex and a cloth or Kim- wipe. The parts can then be polished with a dry cloth or Kim-Wipe without fear of scratching the coating. We have found that the polish or (burnishing) of the coated parts actually decreases the surface friction of the coating, improving its hydrophobic properties.

Figure #2 shows the reflection of one of the exposure parts before and after 1,2,and 3-month exposure, where the part is scanned before and after cleaning.

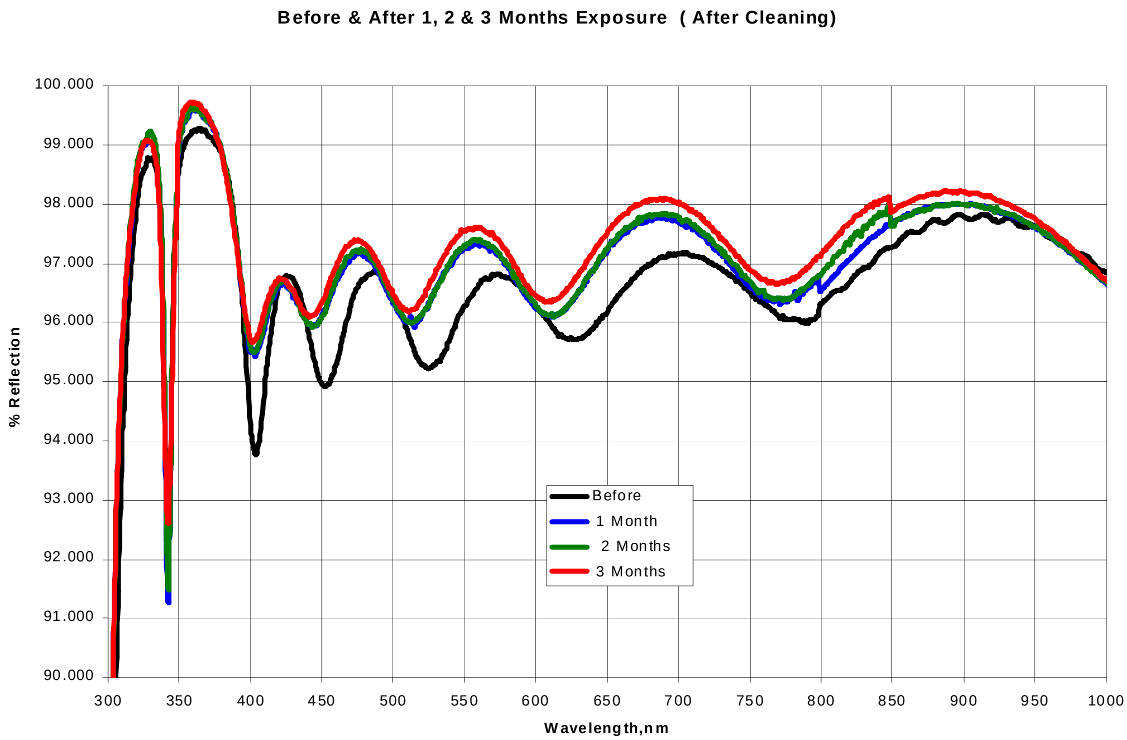

Fig. 2.

Please note the degradation in reflection prior to cleaning (Black Line). After cleaning with a standard glass cleaner and cloth the reflection returns to values equal to or better than the original values.

Conclusions

We have developed a design and process for sputter-depositing durable silver based mirror coatings and other thin film optical coatings in a box-coater. The mirrors have extended wavelength reflection (300-2500nm), and have outstanding environmental durability. This is accomplished using six-inch diameter sputter guns, without the assist of any additional ion guns or plasma enhancing devices. Future plans call for scaling the process in the same system to coat a 1.1 meter substrate.

References

1.) Web-site: http://www-eng.llnl.gov/silver_mirror/index.html

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